

1 ELECTRONIC WATERMARKING METHOD AND APPARATUS FOR COMPRESSED
2 AUDIO DATA, AND SYSTEM THEREFOR

3 Field of the Invention

4 The present invention relates to a method and a system for
5 embedding, detecting and updating additional information,
6 such as copyright information, relative to compressed
7 digital audio data, and relates in particular to a technique
8 whereby an operation equivalent to an electronic
9 watermarking technique performed in a frequency domain can
10 be applied for compressed audio data.

11 Background Art

12 As a technique for the electronic watermarking of audio
13 data, there is a Spread Spectrum method, a method for
14 employing a polyphase filter, or a method for transforming
15 data in a frequency domain and for embedding the resultant
16 data. The method for embedding and detecting information in
17 the frequency domain has merit in that an auditory
18 psychological model can be easily employed, in that high
19 tone quality can be easily provided and in that the
20 resistance to transformation and noise is high. However,
21 the target for the conventional audio electronic
22 watermarking technique is limited to digital audio data that
23 is not compressed. For the Internet distribution of audio

1 data, generally the audio data are compressed, because of
2 the limitation imposed by the communication capacity, and
3 the compressed data are transmitted to users. Thus, when
4 the conventional electronic watermarking technique is
5 employed, it is necessary for the compressed audio data be
6 decompressed, for the obtained data to be embedded and for
7 the resultant data to be compressed again. The calculation
8 time required for this series of operations is extended for
9 the advanced audio compression technique that implements
10 both high tone quality and high compression efficiency. How
11 long it takes before a user can listen to audio data greatly
12 effects the purchase intent of a user. Therefore, there is
13 a demand for a process whereby the embedding, changing or
14 updating of additional information can be performed while
15 the audio data are compressed. However, there is presently
16 no known method available for embedding additional
17 information directly into compressed digital audio data, and
18 for changing or detecting the additional information.

19 SUMMARY OF THE INVENTION

20 To resolve the above shortcoming, it is one object of the
21 present invention to provide a method and a system with
22 which information embedded in compressed digital audio data
23 can be directly operated.

24 It is one more object of the present invention to provide a
25 method and a system with which additional information can be

1 embedded in compressed digital audio data.

2 It is another object of the present invention to provide a
3 method and a system for which only a small memory capacity
4 is required in order to embed additional information in
5 digital audio data.

6 It is an additional object of the present invention to
7 provide a method and a system with which minimized
8 additional information can be embedded in digital audio
9 data.

10 It is a further object of the present invention to provide a
11 method and a system with which additional information
12 embedded in compressed digital audio data can be detected
13 without the decompression of the audio data being required.

14 It is yet one more object of the present invention to
15 provide a method and a system with which additional
16 information embedded in compressed digital audio data can be
17 changed without the decompression of the audio data being
18 required.

19 BRIEF DESCRIPTION OF THE DRAWINGS:

20 These and other aspects, features, and advantages of the
21 present invention will become apparent upon further
22 consideration of the following detailed description of the

1 invention when read in conjunction with the following
2 drawing.

3 Fig. 1 is a block diagram illustrating an apparatus for
4 embedding additional information directly in compressed
5 audio data.

6 Fig. 2 is a diagram showing an example for a window length
7 and a window function.

8 Fig. 3 is a diagram showing the relationship existing
9 between a window function and MDCT coefficients.

10 Fig. 4 is a block diagram of an MDCT domain that corresponds
11 to a frame along a time axis.

12 Fig. 5 is a specific diagram showing a sine wave.

13 Fig. 6 is a diagram showing an example for embedding
14 additional information in an adjacent frame.

15 Fig. 7 is a diagram showing a portion of a basis for which
16 the MDCT has been performed.

17 Fig. 8 is a diagram showing an example of the separation of
18 a basis.

19 Fig. 9 is a block diagram showing an additional information
20 embedding system according to the present invention.

1 Fig. 10 is a block diagram showing an additional information
2 detection system according to the present invention.

3 Fig. 11 is a block diagram showing an additional information
4 updating system according to the present invention.

5 Fig. 12 is a diagram showing the general hardware
6 arrangement of a computer.

7 Description of the Symbols

- 8 1: CPU
9 2: Bus
10 4: Main memory
11 5: Keyboard/mouse controller
12 6: Keyboard
13 7: Pointing device
14 8: Display adaptor card
15 9: Video memory
16 10: DAC/LCDC
17 11: Display device
18 12: CRT display
19 13: Hard disk drive
20 14: ROM
21 15: Serial port
22 16: Parallel port
23 17: Timer
24 18: Communication adaptor
25 19: Floppy disk controller

- 1 20: Floppy disk drive
- 2 21: Audio controller
- 3 22: Amplifier
- 4 23: Loudspeaker
- 5 24: Microphone
- 6 25: IDE controller
- 7 26: CD-ROM
- 8 27: SCSI controller
- 9 28: MO
- 10 29: CD-ROM
- 11 30: Hard disk drive
- 12 31: DVD
- 13 32: DVD
- 14 100: System

15 DETAILED DESCRIPTION OF THE INVENTION:

16 Additional information embedding system

17 To achieve the above objects, according to the present
18 invention, a system for embedding additional information in
19 compressed audio data comprises:

- 20 (1) means for extracting MDCT (Modified Discrete Cosine
- 21 Transform) coefficients from the compressed audio data;
- 22 (2) means for employing the MDCT coefficients to calculate a
- 23 frequency component for the compressed audio data;

1 (3) means for embedding additional information in the
2 frequency component obtained in a frequency domain;

3 (4) means for transforming into MDCT coefficients the
4 frequency component in which the additional information is
5 embedded; and

6 (5) means for using the MDCT coefficients, in which the
7 additional information is embedded, to generate compressed
8 audio data.

9 Additional information updating system

10 Further, according to the present invention, a system for
11 updating additional information embedded in compressed audio
12 data comprises:

13 (1) means for extracting MDCT coefficients from the
14 compressed audio data;

15 (2) means for employing the MDCT coefficients to calculate a
16 frequency component for the compressed audio data;

17 (3) means for detecting the additional information in the
18 frequency component that is obtained;

19 (3-1) means for changing, as needed, the additional
20 information for the frequency component;

1 (4) means for transforming into MDCT coefficients the
2 frequency component in which the additional information is
3 embedded; and

4 (5) means for using the MDCT coefficients, in which the
5 additional information is embedded, to generate compressed
6 audio data.

7 Additional information detection system

8 Further, according to the present invention, a system for
9 detecting additional information embedded in compressed
10 audio data comprises:

11 (1) means for extracting MDCT coefficients from the
12 compressed audio data;

13 (2) means for employing the MDCT coefficients to calculate a
14 frequency component for the compressed audio data; and

15 (3) means for detecting the additional information in the
16 frequency component that is obtained.

17 It is preferable that the means (2) calculate the frequency
18 component for the compressed audio data using a precomputed
19 table in which a correlation between MDCT coefficients and
20 frequency components is included.

21 It is also preferable that the means (4) transforms the

1 frequency component into the MDCT coefficients by using a
2 precomputed table that includes a correlation between MDCT
3 coefficients and frequency components.

4 In addition, it is preferable that the means (3) for
5 embedding the additional information in the frequency domain
6 divide an area for embedding one bit by the time domain, and
7 calculate a signal level for each of the individual obtained
8 area segments, while embedding the additional information in
9 the frequency domains in accordance with the lowest signal
10 level available for each frequency.

11 Correlation table generation method

12 According to the present invention, for at least one window
13 function and one window length employed for compressing
14 audio data, a method for generating a table including a
15 correlation between MDCT coefficients and frequency
16 components comprises:

17 (1) a step of generating a basis which is used for
18 performing a Fourier transform for a waveform along a time
19 axis;

20 (2) a step of multiplying a window function by a
21 corresponding waveform that is generated by using the basis;

22 (3) a step of performing an MDCT process, for the result
23 obtained by the multiplication of the window function, and

1 of calculating an MDCT coefficient; and

2 (4) a step of correlating the basis and the MDCT
3 coefficient. The example basis can be a sine wave and a
4 cosine wave.

5 Operation of additional information embedding system

6 The system for embedding additional information in
7 compressed audio data, first extracts compressed MDCT
8 coefficients from compressed digital audio data. Then, the
9 system employs MDCT coefficients sequence that have been
10 calculated and stored in a table in advance to obtain the
11 frequency component of the audio data. Thereafter, the
12 system employs the method for embedding additional
13 information in a frequency domain to calculate an embedded
14 frequency signal, and subsequently, the system employs the
15 table to transform the embedded frequency signal into a MDCT
16 coefficient, and adds the obtained MDCT coefficient to the
17 MDCT coefficient of the audio data. The resultant MDCT
18 coefficients are defined as new MDCT coefficients for the
19 audio data, and are again compressed; the resultant data
20 being regarded as watermarked digital audio data.

21 According to the method of the invention for embedding the
22 minimum data, a frame for the embedding therein of one bit
23 is divided at a time domain, a signal level is calculated
24 for each of the frame segments, and the upper embedding
25 limit is obtained in accordance with the lowest signal level

1 available for each frequency.

2 Operation performed for correlation table

3 A table for correlating the MDCT coefficient and the
4 frequency component is obtained in which representation of
5 each basis of a Fourier transformation relative to the MDCT
6 coefficient is calculated in advance in accordance with a
7 frame length (a window function and a window length). Thus,
8 an operation on the compressed audio data can be performed
9 directly.

10 The means for reducing the memory size that is required for
11 the correlation table employs the periodicity of the basis,
12 such as a sine wave or a cosine wave, to prevent the storage
13 of redundant information. Or, instead of storing in the
14 table the MDCT results obtained for the individual bases
15 using the Fourier transformation, each basis is divided into
16 several segments, and corresponding MDCT coefficients are
17 stored so that the memory size required for the table can be
18 reduced.

19 Operation of additional information detection system

20 The system of the invention employed detecting additional
21 information in compressed audio data, recovers coded MDCT
22 coefficients and employs the same table as is used for the
23 embedding system to perform a process equivalent to the
24 detection in the frequency domain and the detection of bit

1 information and a code signal.

2 Operation of additional information updating system

3 The system of the invention, used for updating additional
4 information embedded in compressed audio data, recovers the
5 coded MDCT coefficients and employs the same method as the
6 detection system to detect a signal embedded in the MDCT
7 coefficients. Only when the strength of the embedded signal
8 is insufficient, or when a signal that differs from a signal
9 to be embedded is detected and updating is required, the
10 same method is employed as that used by the embedding system
11 to embed additional information in the MDCT coefficients.
12 The newly obtained MDCT coefficients are thereafter recorded
13 so that they can be employed as updated digital audio data.

14 Preferred Embodiment

15 First, definitions of terms will be given before the
16 preferred embodiment of the invention is explained.

17 Sound compression technique

18 Compressed data for the present invention are electronic
19 compressed data for common sounds, such as voices, music and
20 sound effects. The sound compression technique is well
21 known as MPEG1 or MPEG2. In the specification, this
22 compression technique is generally called the sound
23 compression technique, and the common sounds are described

1 as sound or audio.

2 * Compressed state

3 The compressed state is the state wherein the amount of
4 audio data is reduced by the target sound compression
5 technique, while deterioration of the sound is minimized.

6 * Non-compressed state

7 The non-compressed state is a state wherein an audio
8 waveform, such as a WAVE file or an AIFF file, is described
9 without being processed.

10 * Decode the compressed state

11 This means "convert from the compressed state of the audio
12 data to the non-compressed state." This definition is also
13 applied to "shifting to the non-compressed state."

14 * MDCT transform (Modified Discrete Cosine Transform)

15 Equation 1

16 [All the equations are tabulated at the end of the text of
17 this description, just before the claims.]

18 X_n denotes a sample value along the time axis, and n is an
19 index along the time axis.

1 Mk denotes a MDCT coefficient, and k is an integer of from 0
2 to $(N/2)-1$, and denotes an index indicating a frequency.

3 In the MDCT transform, the sequence X_0 to $X(N-1)$ along the
4 time axis are transformed into the sequence M_0 to $M((N/2)-1)$
5 along the frequency axis. While the MDCT coefficient
6 represents one type of frequency component, in this
7 specification, the "frequency component" means a coefficient
8 that is obtained as a result of the DFT transform.

9 * DFT transform (Discrete Fourier Transform)

10 Equation 2

11 X_n denotes a sample value along the time axis, and n denotes
12 an index along the time axis.

13 R_k denotes a real number component (cosine wave component);
14 I_k denotes an imaginary number component (sine wave
15 component); and k is an integer of from 0 to $(N/2)-1$, and
16 denotes an index indicating a frequency. The discrete
17 fourier transform is a transformation of the sequence X_0 to
18 $X(N-1)$ along the time axis into the sequences R_0 to
19 $R((N/2)-1)$, and I_0 to $I((N/2)-1)$ along the frequency axis.
20 In this specification, "frequency component" is the general
21 term for the sequences R_k and I_k .

22 * Window function

1 This function is to be multiplied by the sample value before
2 the MDCT is performed. Generally, the sine function or the
3 Kaiser function is employed.

4 * Window length

5 The window length is a value that represents the shape or
6 length of a window function to be multiplied with data in
7 accordance with the characteristic of the audio data, and
8 that indicates whether the MDCT should be performed for
9 several samples.

10 Fig. 1 is a block diagram showing the processing performed
11 by an apparatus for directly embedding additional
12 information in compressed audio data. A block 110 is a
13 block for extracting MDCT coefficients sequence from
14 compressed audio data that are entered. A block 120 is a
15 block for employing the extracted MDCT coefficients to
16 calculate the frequency component of the audio data. A
17 block 130 is a block for embedding additional information in
18 the obtained frequency component of a frequency domain. A
19 block 140 is a block for transforming the frequency
20 component using the additional information embedded in an
21 MDCT coefficient. And finally, a block 150 is a block for
22 generating compressed audio data by using the MDCT
23 coefficient obtained by the block 140.

24 The blocks 120 and 130 employ a correlation table for the

1 MDCT coefficient and the frequency to perform a fast
2 transform. In this invention, the representations of the
3 bases of the Fourier transform in the MDCT domain are
4 entered in advance in the table, and are employed for the
5 individual embedding, detection and updating systems. An
6 explanation will now be given for the correlation table for
7 the MDCT coefficient and the frequency and the generation
8 method therefor, the systems used for embedding, detecting
9 and updating compressed audio data, and other associated
10 methods.

11 Correlation table for MDCT coefficients and frequency
12 components

13 Audio data must be transformed into a frequency domain in
14 order to employ an auditory psychological model for
15 embedding calculation. However, a very extended calculation
16 time is required to perform inverse transformations, for the
17 audio data that are represented as MDCT coefficients, and to
18 perform the Fourier transforms for audio data at the time
19 domain. Thus, a correlation between the MDCT coefficients
20 and the frequency components is required.

21 If the audio data are compressed by performing the MDCT for
22 a constant number of samples without a window function, the
23 MDCT employs the cosine wave with a shifted phase as a
24 basis. Therefore, the difference from a Fourier transform
25 consists only of the shifting of a phase, and a preferable
26 correlation can be expected between the MDCT domain and the

1 frequency domain. However, to obtain improved tone quality,
2 the latest compression technique changes the shape or the
3 length of the window function to be multiplied (hereinafter
4 refereed to as a window length) in accordance with the
5 characteristic of the audio data. Thus, a simple
6 correlation between a specific frequency for the MDCT and a
7 specific frequency for a Fourier transform can not be
8 obtained, and since the correlation can not be acquired
9 through calculation, it must be stored in a table.

10 Fig. 2 is a diagram showing window length and window
11 function examples. While this invention can be applied for
12 various compressed data standards, in this embodiment, the
13 MPEG2 standards are employed. For MPEG2 AAC (Advanced Audio
14 Coding), for example, a window function normally having a
15 window length of 2048 samples is multiplied to perform the
16 MDCT. For a portion where sound is drastically altered, a
17 window function having a window length of 256 samples is
18 multiplied to perform the MDCT, so that a type of
19 deterioration called pre-echo is prevented. A normal frame
20 for which 2048 samples is a unit is called an
21 ONLY_LONG_SEQUENCE, and is written using 1024 MDCT
22 coefficients that are obtained from one MDCT process. A
23 frame for which 256 samples is a unit is called an
24 EIGHT_SHORT_SEQUENCE, and is written using eight pairs of
25 MDCT 128 coefficients that are obtained by repeating the
26 MDCT eight times, for 256 samples each time, with each frame
27 half overlapping its adjacent frame. Further, asymmetric
28 window functions called a LONG_START_SEQUENCE and a

1 LONG_STOP_SEQUENCE are also employed to connect the above
2 frames.

3 Fig. 3 is a diagram showing the correlation between the
4 window functions and the MDCT coefficients sequence. For
5 the MPEG2 AAC, the window functions are multiplied by the
6 audio data along the time axis, for example, in the order
7 indicated by the curves in Fig. 3, and the MDCT coefficients
8 are written in the order indicated by the thick arrows.
9 When the window length is varied, as in this example, the
10 bases of a Fourier transform can not simply be transformed
11 into a number of MDCT coefficients.

12 Therefore, to embed additional information, the correlation
13 table of this invention does not depend on the window
14 function (a signal added during the additional information
15 embedding process should not depend on a window function
16 when the signal is decompressed and developed along the time
17 axis). Therefore, when an embedding method is employed that
18 depends on the shape of the window function and the window
19 length, the embedding and the detection of the compressed
20 audio data can be performed, and the window function that is
21 used can be identified when the data are decompressed.

22 The correlation table of the invention is generated so that
23 frames in which additional information is to be embedded do
24 not interfere with each other. That is, in order to embed
25 additional information, the MDCT window must be employed as
26 a unit, and when the data are developed along the time axis,

1 one bit must be embedded in a specific number of samples,
2 which together constitute one frame. Since for the MDCT,
3 target frames for the multiplication of a window overlap
4 each other 50%, a window that extends over a plurality of
5 frames is always present (a block 3 in Fig. 4 corresponds to
6 such a window). When additional information is simply
7 embedded in one of these frames, it affects the other
8 frames. And when data embedding is not performed, the data
9 embedding intensity is reduced, as is detection efficiency.
10 Signals indicating different types of additional information
11 are embedded in the first and the second halves of a frame.

12 The correlation table is employed when a frequency component
13 is to be calculated using the MDCT coefficient to embed
14 additional information, when an embedded signal obtained at
15 the frequency domain is to be again transformed into an MDCT
16 coefficient, and when a calculation corresponding to a
17 detection in a frequency domain is to be performed in the
18 MDCT domain. Since the detection and the embedding of a
19 signal are performed in order during the updating process,
20 all the transforms described above are employed in the
21 updating process.

22 Method for generating a correlation table when the length of
23 a window function is unchanged

24 First, an explanation will be given for the table generation
25 method when a window length is constant, and for the
26 detection and embedding methods that use the table. These

1 methods will be extended later for use by a plurality of
2 window lengths. Assume that the window function is
3 multiplied along the time axis by audio data consisting of N
4 samples and the MDCT is performed to obtain $N/2$ MDCT
5 coefficients, and that $N/2$ MDCT coefficients are employed
6 and written as one block (i.e., a constant window length is
7 defined as N samples). Hereinafter, if not specifically
8 noted, the term "block" represents $N/2$ MDCT coefficients.
9 The audio data along the time axis that correspond to two
10 sequential blocks are those where there is a 50%, i.e., $N/2$
11 samples, overlap.

12 The target of the present invention is limited to an
13 embedding ratio for the embedding of one bit in relative
14 samples integer times $N/2$. In this embodiment, the number
15 of samples required along the time axis to embed one bit is
16 defined as $n \times N/2$, which is called one frame. Due to the
17 previously mentioned 50% overlapped property there is also a
18 block that is extended across two sequential frames along
19 the time axis. Fig. 4 is a specific diagram showing two
20 frames extended along the time axis when $n=2$ that correspond
21 to five blocks in the MDCT domain. The audio data along the
22 time axis are shown in the lower portion in Fig. 4, the MDCT
23 coefficients sequence are shown in the upper portion, and
24 elliptical arcs represent the MDCT targets. Block 3 is a
25 block extending half way across Frame 1 and Frame 2.

26 Since the embedding operation is performed for the
27 independent frames, the correlation between the frequency

1 component and the MDCT coefficient for each frame need only
2 be required for the table. In other words, adjacent frames
3 in which embedding is performed should not affect each
4 other. Therefore, for each basis of a Fourier transform
5 having a cycle of $N/(2 \times m)$, the MDCT coefficients sequence
6 obtained using the following methods are employed to prepare
7 a table. In this case, m is an integer equal to or smaller
8 than $N/2$. Fig. 5 is a diagram showing a sine wave for $n=2$
9 and $m=1$.

10 There are $n+1$ blocks present that are associated with one
11 frame, and the first and the last blocks also extend into
12 the respective succeeding and preceding frames (blocks 1 and
13 3 in Fig. 5). Thus, assume a waveform (the thick line
14 portion in Fig. 5) is obtained by connecting $N/2$ samples
15 having a value of 0 before and after the basis waveform that
16 has an amplitude of 1.0 and a length equivalent to one
17 frame. When a window function (corresponding to an
18 elliptical arc in Fig. 5) is multiplied by N samples, while
19 50% of the first part of the waveform is overlapped, and the
20 MDCT is performed, this waveform can be represented by using
21 the MDCT coefficients. If the IMDCT is performed for the
22 obtained MDCT coefficients sequence, the preceding and
23 succeeding $N/2$ samples have a value of 0.

24 Fig. 6 is a diagram showing an example wherein additional
25 information is embedded in adjacent frames. When samples
26 having a value of 0 are added as shown in Fig. 6, the
27 interference produced by embedding performed in adjacent

1 frames can be prevented. In the data detection process and
 2 the frequency component calculation process, detection
 3 results and frequency components can be obtained that are
 4 designated for a pertinent frame and that are not affected
 5 by preceding and succeeding frames. If a value of 0 is not
 6 compensated for, adjacent frames affect each other in the
 7 embedding and detection process.

8 The processing performed to prepare the table is as follows.

9 Step 1: First, calculations are performed for a cosine wave
 10 having a cycle of $N/2 \times n/k$, an amplitude of 1.0 and a length
 11 of $N/2 \times n$. This cosine wave corresponds to the k -th basis
 12 when a Fourier transform is to be performed for the $N/2 \times n$
 13 samples.

$$\begin{aligned} 14 \quad f(x) &= \cos(2\pi / (N/2 \times n/k) \times x) & (0 \leq x < N/2 \times n) \\ 15 \quad &= \cos(4k\pi / (N \times n) \times x) \end{aligned}$$

16 Step 2: $N/2$ samples having a value of 0 are compensated for
 17 at the first and the last of the waveform (Fig. 5).

$$\begin{aligned} 18 \quad g(y) &= 0 & (0 \leq y < N/2) \\ 19 \quad &f(y - N/2) & (N/2 \leq y < N/2 \times (n+1)) \\ 20 \quad &0 & (N/2 \times (n+1) \leq y < N/2 \times (n+2)) \end{aligned}$$

1 Step 3: The samples $N/2 \times (b-1)$ th to $N/2 \times (b+1)$ th are
2 extracted. Here b is an integer of from 1 to $n+1$, and for
3 all of these integers the following process is performed.

$$4 \quad h_b(z) = g(z + N/2 \times (b-1)) \quad (0 \leq z < N)$$

5 Step 4: The results are multiplied by a window function.

$$6 \quad h_b(z) = h_b(z) \times \text{win}(z) \quad (0 \leq z < N, \text{win}(z) \text{ is a window} \\ 7 \text{ function})$$

8 Step 5: The MDCT process is performed, and the obtained $N/2$
9 MDCT coefficients are defined as vectors $V_{r,b,k}$.

$$10 \quad V_{r,b,k} = \text{MDCT}(h_b(z))$$

11 Since the MDCT transform is an orthogonal transform and each
12 basis of a Fourier transform is a linear independence, $V_{r,b,k}$
13 are orthogonal for a k having a value of 1 to $N/2$.

14 Step 6: $V_{r,b,k}$ is obtained for all the combinations (k, b) ,
15 and each matrix $T_{r,b}$ is formed.

$$16 \quad T_{r,b} = (V_{r,b,1}, V_{r,b,2}, V_{r,b,3}, \dots, V_{r,b,N/2})$$

17 The vector that is obtained for a sine wave using the same
18 method is defined as v_i, b, k , and the matrix is defined as
19 T_i, b . Each sequence is an MDCT coefficient sequence that
20 represents the sine wave of a value of 1. Since there are 1

1 to $n+1$ blocks, $2 \times (n+1)$ matrixes are obtained.

2 Transform from a frequency domain into an MDCT domain

3 Assume that the audio data in the frequency domain are
 4 represented as $R + jI$, where j denotes an imaginary number
 5 element, R denotes a real number element and I is the $N/2$ th
 6 order real number vector that represents an imaginary number
 7 element. The k element corresponds to a basis having a
 8 cycle of $(N/2) \times n/k$ samples. The MDCT coefficient sequence
 9 M_b is obtained as the sum of the vectors of MDCT
 10 coefficients sequence, which is obtained by transforming
 11 each frequency component separately into an MDCT domain, and
 12 can be represented as $M_b = T_{r,b} + T_{i,b}I$. In this case, b is an
 13 integer of from 1 to $n+1$, and corresponds to each block. M_1
 14 and M_{n+1} are MDCT coefficients sequence for a block that
 15 extends across portions of adjacent frame.

16 Transform from an MDCT domain into a frequency domain

17 Here, $v_{i,b,k}$ and the $v_{r,b,k}$ are orthogonal to each other and
 18 form an MDCT domain. Thus, when a specific MDCT coefficient
 19 sequence is given, and when the inner product is calculated
 20 for the MDCT coefficient sequence and $v_{r,b,k}$ or $v_{i,b,k}$, the
 21 element in the corresponding direction of the M_b can be
 22 obtained that represents respectively a real number element
 23 and/or an imaginary number element in the frequency domain.
 24 The MDCT coefficients sequence for $(n+1)$ blocks associated
 25 with one frame are collectively processed to obtain the

1 frequency component for the pertinent frame.

2 Equation 3

3 Correlation table generation method when a window function
4 is changed in audio data

5 Assume that the types of window functions that could be
6 employed for compression are listed. All the window lengths
7 are dividers having a maximum window length of N. For a
8 block having an N/W (W is an integer) sample window length,
9 assume that the MDCT is repeated for the N/W sample W times,
10 with 50% overlapping, and that as a result W pairs of N/(2W)
11 MDCT coefficients, i.e., a total of N/2 coefficients, are
12 written in the block. Further, assume that in the first
13 MDCT process N/W samples beginning with the "offset" sample
14 in the block are transformed. For example, where for the
15 EIGHT_SHORT_SEQUENCE of the MPEG2 AAC, N=2048, W=8 and
16 offset=448. As a result of repeating the eight MDCT
17 processes for 256 samples with 50% overlapping, eight pairs
18 of 128 MDCT coefficients are written along the time axis
19 (see Figs. 2 and 3).

20 Table generation method

21 The table for the window length N/W is generated as follows.
22

23 Step 1: The same as when the length of the window function

1 is unchanged.

2 Step 2: The same as when the length of the window function
3 is unchanged.

4 Step 3: The N/W sample corresponding to the W -th window is
5 extracted. W is an integer of from 1 to W . b is an integer
6 of from 1 to $n+1$. The following processing must be
7 performed for all the combinations of b and w .

8
$$h_{b,w}(z) = g(z + N/2 \times (b-1) + N/2/W \times w + \text{offset})$$

9
$$(0 \leq z < N/W)$$

10 Step 4: The results are multiplied by a window function.

11
$$h_{b,w}(z) = h_{b,w}(z) \times \text{win}(z)$$
 $(0 \leq z < N/W: \text{win}(z) \text{ is a}$
12
$$\text{window function})$$

13 Step 5: The MDCT process is performed, and the obtained
14 $N/(2W)$ MDCT coefficients are defined as vectors $v_{r,b,k,w}$.

15
$$v_{r,b,k,w} = \text{MDCT}(h_{b,w}(z))$$

16 Step 6: $v_{r,b,k,w}$ are arranged to define $v_{r,b,k}$.

17 When $v_{r,b,k,w}$ is obtained for all the " w "s having a value of 1
18 to W , they are arranged vertically to obtain vector $v_{r,b,k}$.

1 Fig. 7 is a diagram showing the portion of a basis for
2 which, with $n=2$, $b=2$, $k=1$ and $W=8$, the MDCT process has been
3 performed to obtain the coefficients $v_{r,2,1,w}$.

4 Step 7: The coefficients $v_{r,b,k}$ are obtained for all the
5 combinations (k, b) , and the coefficients $v_{r,b,k}$ for k having
6 values of 1 to $N/2$ are arranged horizontally to constitute
7 $T_{W,r,b}$.

8 Since each $v_{r,b,k,w}$ is a vector of $N/(2w)$ rows by one column,
9 this matrix is a square matrix of $N/2$ rows by $N/2$ columns.
10 Each column illustrates how a cosine wave having a value of
11 1 is represented as the MDCT coefficients sequence in the
12 b -th block having a window length of N/W . Similarly, the
13 matrix $T_{W,i,b}$ is obtained in the sine wave. Since from 1 to
14 $n+1$ block numbers b are provided, for this window length, 2
15 $\times (n+1)$ matrixes are obtained. In addition, the table is
16 prepared in accordance with the window length and the types
17 of window functions.

18 Transform from the frequency domain to the MDCT domain

19 The difference from a case where only one type of window
20 length is employed is that block information is read from
21 compressed audio data and that a different matrix is
22 employed in accordance with the window function that is used
23 for each block. Since the matrix is varied for each block,
24 the MDCT coefficient sequence M_b is adjusted in order to
25 cope with the window function and the window length that are

1 employed. The waveform, which is obtained when the IMDCT is
2 performed for the MDCT coefficient sequence M_b in the time
3 domain, and the frequency component, which is obtained by
4 performing a Fourier transform in the frequency domain, do
5 not depend on the window function and the window length.
6 The MDCT coefficient sequence M_b is obtained using $M_b =$
7 $T_{w,r,b}R + T_{w,i,b}I$.

8 Transform from the MDCT domain to the frequency domain

9 When $T_{w,r,b}$ is employed instead of $T_{r,b}$, the transform in the
10 frequency domain can be performed in the same manner. When
11 the matrix is changed in accordance with the window function
12 and the window length, a true frequency component can be
13 obtained that does not depend on the window function and the
14 window length.

15 Equation 4

16 Method for reducing a memory capacity required for the table

17 Since the matrix has a size of $(N/2) \times (N/2)$, the table
18 generated by this method is constituted by $2 \times (n+1) \times (N/2)$
19 $\times (N/2) = (n+1) \times N/2/2$ MDCT coefficients (floating-point
20 numbers). However, since the contents of this table tend to
21 be redundant, the memory capacity that is actually required
22 can be considerably reduced.

23 Method 1: method for using the periodicity of the basis.

1 The periodicity of the basis can be employed as one method.
2 According to this method, since several $V_{r,b,k}$ are identical,
3 this portion is removed.

4 When m is an integer, the cosine wave that is $N/2 \times m$ samples
5 ahead is represented as

6
$$f(x + N/2 \times m) = \cos(4k\pi / (N \times n) \times (x + N/2 \times m))$$

7
$$= \cos(4k\pi / (N \times n) \times x + 4k\pi / (N \times n) \times N/2 \times m)$$

8
$$= \cos(4k\pi / (N \times n) \times x + 2\pi k \times m / n).$$

9 Therefore, in case a where $(k \times m) / n$ is an integer,

10
$$f(x + N/2 \times m) = f(x) \quad (\text{limited to a range } 0 \leq x \leq N/2 \times (n - m))$$

11
$$g(y + N/2 \times m) = g(y) \quad (\text{limited to a range } N/2 \leq y \leq N/2 \times (n - m + 1)).$$

12 Thus,

13
$$h_{b+m}(z) = h_b(z) \quad (\text{limited to a range } 2 \leq b \leq n - m),$$

14 and

15
$$V_{r,b+m,k} = V_{r,b,k} \quad (\text{limited to a range } 2 \leq b \leq n - m)$$

16 is obtained. The range is limited because of the range

1 defined for $f(x)$.

2 In case b where $(k \times m)/n$ is an irreducible fraction that can
3 be represented by integer/2,

$$4 \quad f(x + N/2 \times m) = -f(x)$$

5 And

$$6 \quad h_{b+m}(z) = -h_b(z).$$

7 Thus,

$$8 \quad V_{r,b+m,k} = -V_{r,b,k}.$$

9 The range limitation is the same as it is for case a.

10 In case c where $(k \times m)/n$ is an irreducible fraction that can
11 be represented by $(4 \times \text{integer} + 1)/4$,

$$12 \quad f(x + N/2 \times m) = \cos(4k\pi/(N \times n) \times x + \pi(\text{even number} + 1/2))$$

$$13 \quad = -\sin(4k\pi/(N \times n) \times x).$$

14 Thus,

$$15 \quad V_{r,b+m,k} = -V_{i,b,k}.$$

16 In case d where $(k \times m)/n$ is an irreducible fraction that can

1 be represented by $(4 \times \text{integer} + 3)/4$,

2 $f(x + N/2 \times m) = \cos(4k\pi/(N \times n) \times x + \pi(\text{odd number} + 1/2))$

3 $= \sin(4k\pi/(N \times n) \times x)$.

4 Thus,

5 $V_{r,b+m,k} = V_{i,b,k}$.

6 The range limitation is the same as it is for case a.

7 Therefore, $V_{r,b+m,k}$, which establishes conditions a to d, can
8 be replaced by another vector, and this is applied to $V_{i,b,k}$.

9 Thus, instead of storing the matrixes $T_{r,b}$ and $T_{i,b}$ being
10 unchanged, only the following minimum elements need be
11 stored. The following minimum elements are as follows.

12 * vectors $V_{r,b,k}$ and $V_{i,b,k}$ that do not establish the conditions
13 a to d

14 * information concerning the positive or negative sign that
15 is to be added to a vector that is to be used for each
16 column in the matrixes $T_{r,b}$ and $T_{i,b}$.

17 For the actual transform between the MDCT domain and the
18 frequency domain, the vectors $V_{r,b,k}$ and $V_{i,b,k}$ are employed
19 instead of the columns in the matrixes $T_{r,b}$ and $T_{i,b}$ to perform
20 a calculation equivalent to the matrix operation. The

1 transform from the frequency domain to the MDCT domain is
2 represented as follows.

3 Equation 5

4 Another appropriate vector is employed for a portion wherein
5 a vector is standardized. The transform from the MDCT
6 domain to the frequency domain is performed by obtaining the
7 following inner product for each frequency component. The
8 following equation is obtained by separating the equation
9 used for the matrixes $T_{r,b}$ and $T_{i,b}$ into its individual
10 components.

11 Equation 6

12 Due to the vector standardization, the required memory
13 capacity depends on "n" to a degree. For example, since
14 only the condition a is established when $n=3$, the required
15 memory capacity is reduced only 8.3%, while when $n=4$, it is
16 reduced 40%.

17 Since the same relation exists between h_b and w as when only
18 one type of window function is provided in a case where the
19 window function is varied, the above standardization can be
20 employed unchanged, and when the same condition is
21 established, the following equation is obtained.

22 Equation 7

1 Method 2: method for separating the basis into preceding and
2 succeeding segments.

3 Furthermore, the linearity of the MDCT is employed to
4 separate the basis of a Fourier transform into individual
5 segments, and the MDCT coefficients sequence obtained by the
6 transform are used to form a table. Then, the application
7 range of the above method 1 can be expanded. Actually, the
8 sum of the vectors of the MDCT coefficients sequence that
9 are stored in the table is employed to represent the basis.
10 Fig. 8 is a diagram showing an example wherein a basis is
11 separated.

12 First, a waveform (thick line on the left in Fig. 8) is
13 divided into the first $N/2$ sample and the last $N/2$ sample
14 for each block. To perform an MDCT for the first $N/2$
15 sample, a waveform having a value of 0 is compensated for by
16 the $N/2$ sample (in the middle in Fig. 8). To perform an
17 MDCT for the last $N/2$ sample, a wave form having a value of
18 0 is compensated for by the $N/2$ sample (on the right in Fig.
19 8). In this example, the MDCT is performed for the first
20 (last) half of the waveform, and the obtained MDCT
21 coefficients sequence are represented by $V_{fore,r,b,k}$ ($V_{back,r,b,k}$).
22 Since the MDCT possesses linearity, the original MDCT
23 coefficient sequence $V_{r,b,k}$ is equal to the sum of the vectors
24 $V_{fore,r,b,k}$ and $V_{back,r,b,k}$.

25 When the basis is separated in this manner, $V_{fore,r,b,k}$ and
26 $V_{back,r,b,k}$ can be used in common even for the portion wherein

1 $V_{r,b,k}$ can not be standardized using method 1. For example,
 2 in Fig. 5, method 1 can not be applied for Block 1 because
 3 $b=1$. However, if each block is separated into first and
 4 last segments, the signs are merely inverted for the MDCT
 5 coefficient sequence $V_{back,r,1,k}$ for Block 1 and the MDCT
 6 coefficient sequence $V_{back,r,2,k}$ for Block 2. Therefore, one of
 7 the MDCT coefficients sequence need not be stored. This can
 8 also be applied for $V_{fore,r,2,k}$ for Block 2, and $V_{fore,r,3,k}$ for
 9 Block 3. $V_{fore,r,1,k}$ for Block 1, and $V_{fore,r,3,k}$ for Block 3 are
 10 always zero vectors.

11 The processing for generating a table using the above method
 12 is as follows.

13 Step 1: The same as when the basis is not separated into
 14 first and second segments.

15 Step 2: The same as when the basis is not separated into
 16 first and second segments.

17 Step 3: First, the "fore" coefficients are prepared. The
 18 $(N/2 \times (b-1))$ -th to the $(N/2 \times b)$ -th coefficients are extracted,
 19 and the $N/2$ sample having a value of 0 is added after them.

$$20 \quad h_{fore,b}(z) = g(z + N/2 \times (b-1)) \quad (0 \leq z < N/2)$$

$$21 \quad \quad \quad 0 \quad \quad \quad (N/2 \leq z < N)$$

22 Step 4: A window function is multiplied.

1 $h_{\text{fore},b}(z) = h_{\text{fore},b}(z) \times \text{win}(z)$

2 $(0 \leq z < N, \text{win}(z) \text{ is a window function})$

3 Step 5: The MDCT process is performed, and the obtained $N/2$

4 MDCT coefficients are defined as vector $V_{\text{fore},r,b,k}$.

5 $V_{\text{fore},r,b,k} = \text{MDCT}(h_{\text{fore},b}(z))$.

6 Step 6: Next, the "back" coefficients are prepared. The

7 $(N/2 \times b)$ -th to the $(N/2 \times (b+1))$ -th coefficients are extracted,

8 and the $N/2$ sample having a value of 0 is added before them.

9 $h_{\text{back},b}(z) = 0$ $(0 \leq z < N/2)$

10 $g(z + N/2 \times (b-1))$ $(N/2 \leq z < N)$

11 Step 7: A window function is multiplied.

12 $h_{\text{back},b}(z) = h_{\text{back},b}(z) \times \text{win}(z)$

13 $(0 \leq z < N, \text{win}(z) \text{ is a window function})$

14 Step 8: The MDCT process is performed, and the obtained $N/2$

15 MDCT coefficients are defined as vector $V_{\text{back},r,b,k}$.

16 $V_{\text{back},r,b,k} = \text{MDCT}(h_{\text{back},b}(z))$.

1 Step 9: $V_{\text{fore},r,b,k}$ and $V_{\text{back},r,b,k}$ are calculated for all the
2 combinations (k,b) , and the matrixes $T_{\text{fore},r,b}$ and $T_{\text{back},r,b}$ are
3 formed.

$$4 \quad T_{\text{fore},r,b} = (V_{\text{fore},r,b,1}, V_{\text{fore},r,b,2}, \dots, V_{\text{fore},r,b,N/2})$$

$$5 \quad T_{\text{back},r,b} = (V_{\text{back},r,b,1}, V_{\text{back},r,b,2}, \dots, V_{\text{back},r,b,N/2})$$

6 In accordance with the linearity of the MDCT,

$$7 \quad V_{r,b,k} = V_{\text{fore},r,b,k} + V_{\text{back},r,b,k},$$

8 and

$$9 \quad T_{r,b} = T_{\text{fore},r,b} + T_{\text{back},r,b}.$$

10 In accordance with this characteristic, for the transform
11 between the MDCT domain and the frequency domain, only an
12 operation equivalent to the operation performed using the
13 $T_{r,b}$ need be performed by using $T_{\text{fore},r,b}$ and $T_{\text{back},r,b}$.

14 The periodicity of the basis is employed under these
15 definitions,

16 in case a where $(k \times m)/n$ is an integer, and under the
17 condition where $b+m=n+1$,

18 $h_{\text{fore},n+1}(z) == h_{\text{fore},b}(z)$ is established. This is because the
19 second half of $h_{\text{fore},b}(z)$ has a value of 0. Thus, the

1 application range for the following equation is expanded,
2 and

$$3 \quad h_{\text{fore},b+m}(z) == h_{\text{fore},b}(z)$$

4 (limited to a range of $2 \leq b \leq n-m+1$).

5 Thus,

$$6 \quad V_{\text{fore},r,b+m,k} == V_{\text{fore},r,b,k}$$

7 (limited to a range of $2 \leq b \leq n-m+1$),

8 and the portions used in common are increased. For $V_{\text{back},r,b,k}$,

9

$$10 \quad h_{\text{back},m+1}(z) == h_{\text{back},1}(z)$$

11 is established even under the condition where $b=1$. This is
12 because the first half of $l(z)$ has a value of zero. The
13 application range for the following equation is expanded,
14 and

$$15 \quad h_{\text{back},b+m}(z) == h_{\text{back},b}(z)$$

16 (limited to a range of $1 \leq b \leq n-m$).

17 Therefore,

1 $V_{back,r,b+m,k} == V_{back,r,b,k}$

2 (limited to a range of $1 \leq b \leq n-m+1$),

3 and the portions used in common are increased. The same
4 range limitation is provided for the cases b, c and d.

5 Method 3: approximating method

6 The final method for reducing the table involves the use of
7 an approximation. Among the MDCT coefficients sequence that
8 correspond to one basis waveform of a Fourier transform, an
9 MDCT coefficient that is smaller than a specific value can
10 approximate zero, and no actual problem occurs. A threshold
11 value used for the approximation is appropriately selected
12 by a trade off between the transform precision and the
13 memory capacity. When the individual systems are so
14 designed that they do not perform a matrix calculation for
15 the portion that approximates zero, the calculation time can
16 also be reduced.

17 Furthermore, when all the coefficients, including large
18 coefficients, approximate rational numbers, which are then
19 quantized, the coefficients can be stored as integers, not
20 as floating-point numbers, so that a savings in memory
21 capacity can be realized.

22 Correlation table generator

1 Information concerning the window is received, and the table
2 is generated and output. As well as the method for
3 generating the correlation table, the information concerning
4 the window includes the frame length N, the length n of a
5 block corresponding to the frame, the offset of the first
6 window, the window function, and "W" for regulating the
7 window length. Basically, the number of tables that are
8 generated is equivalent to the number of window types used
9 in the target sound compression technique.

10 Additional information embedding system

11 Fig. 9 is a block diagram illustrating an additional
12 information embedding system according to the present
13 invention. An MDCT coefficient recovery unit 210 recovers
14 sound MDCT coefficients sequence, and window and other
15 information from compressed audio data that are entered.
16 These data are extracted (recovered) using Huffmann
17 decoding, inverse quantization and a prediction method,
18 which are designated in the compressed audio data. An
19 MDCT/DFT transformer 230 receives the sound MDCT
20 coefficients sequence and the window information that are
21 obtained by the MDCT coefficient recovery unit 210, and
22 employs a table 900 to transform these data into a frequency
23 component. A frequency domain embedding unit 250 embeds
24 additional information in the frequency component that is
25 obtained by the MDCT/DFT transformer 230.

26 In accordance with the window information extracted by the

1 MDCT coefficient recovery unit 210, a DFT/MDCT transformer
2 240 employs the table 900 to transform, into MDCT
3 coefficients sequence, the resultant frequency components
4 that are obtained by the frequency domain embedding unit
5 250. Finally, an MDCT coefficient compressor 220 compresses
6 the MDCT coefficients obtained by the DFT/MDCT transformer
7 240, as well as the window information and the other
8 information that are extracted by the MDCT coefficient
9 recovery unit 210. The compressed audio data are thus
10 obtained. The prediction method, the inverse quantization
11 and the Huffmann decoding, which are designated in the
12 window information and the other information, are employed
13 for the data compression. Through this processing, the
14 additional information is embedded so it corresponds to the
15 operation of the frequency component, and so that even after
16 decompression additional information can be detected using
17 the conventional frequency domain detection method.

18 Additional information detection system

19 Fig. 10 is a block diagram illustrating an additional
20 information detection system according to the present
21 invention. An MDCT coefficient recovery unit 210 recovers
22 sound MDCT coefficients sequence, window information and
23 other information from compressed audio data that are
24 entered. These data are extracted (recovered) using
25 Huffmann decoding, inverse quantization and a prediction
26 method, which are designated in the compressed audio data.
27 An MDCT/DFT transformer 230 receives the sound MDCT

1 coefficients sequence and the window information that are
2 obtained by the MDCT coefficient recovery unit 210, and
3 employs a table 900 to transform these data into frequency
4 components. Finally, a frequency domain detector 310
5 detects additional information in the frequency components
6 that are obtained by the MDCT/DFT transformer 230, and
7 outputs the additional information.

8 Additional information updating system

9 Fig. 11 is a block diagram illustrating an additional
10 information updating system according to the present
11 invention.

12 An MDCT coefficient recovery unit 210 recovers sound MDCT
13 coefficients sequence, window information and other
14 information from compressed audio data that are entered.
15 These data are extracted (recovered) using Huffmann
16 decoding, inverse quantization and a prediction method,
17 which are designated in the compressed audio data.

18 An MDCT/DFT transformer 230 receives the sound MDCT
19 coefficients sequence and the window information that are
20 obtained by the MDCT coefficient recovery unit 210, and
21 employs a table 900 to transform these data into frequency
22 components.

23 A frequency domain updating unit 410 first determines
24 whether additional information is embedded in the frequency

1 components obtained by the MDCT/DFT transformer 230. If
2 additional information is embedded therein, the frequency
3 domain updating unit 410 further determines whether the
4 contents of the additional information should be changed.
5 Only when the contents of the additional information should
6 be changed is the updating of the additional information
7 performed for the frequency components (the determination
8 results may be output so that a user of the updating unit
9 410 can understand it).

10 In accordance with the window information extracted by the
11 MDCT coefficient recovery unit 210, a DFT/MDCT transformer
12 240 employs the table 900 to transform, into MDCT
13 coefficients sequence, the frequency components that have
14 been updated by the frequency domain updating unit 250.

15 Finally, an MDCT coefficient compressor 220 compresses the
16 MDCT coefficients sequence obtained by the DFT/MDCT
17 transformer 240, as well as the window information and the
18 other information that are extracted by the MDCT coefficient
19 recovery unit 210. The compressed audio data are thus
20 obtained. The prediction method, the inverse quantization
21 and the Huffmann decoding, which are designated in the
22 window and the other information, are employed for the data
23 compression.

24 General hardware arrangement

25 The apparatus and the systems according to the present

1 invention can be carried out by using the hardware of a
2 common computer. Fig. 12 is a diagram illustrating the
3 hardware arrangement for a general personal computer. A
4 system 100 comprises a central processing unit (CPU) 1 and a
5 main memory 4. The CPU 1 and the main memory 4 communicate,
6 via a bus 2 and an IDE controller 25, with a hard disk drive
7 (HDD) 13, which is an auxiliary storage device (or a storage
8 medium drive, such as a CD-ROM 26 or a DVD 32). Similarly,
9 the CPU 1 and the main memory 4 communicate, via a bus 2 and
10 a SCSI controller 27, with a hard disk drive 30, which is an
11 auxiliary storage device (or a storage medium drive, such as
12 an MO 28, a CD-ROM 29 or a DVD 31). A floppy disk drive
13 (FDD) 20 (or an MO or a CD-ROM drive) is connected to the
14 bus 2 via a floppy disk controller (FDC) 19.

15 A floppy disk is inserted into the floppy disk drive 20.
16 Stored on the floppy disk and the hard disk drive 13 (or the
17 CD-ROM 26 or the DVD 32) are a computer program, a web
18 browser, the code for an operating system and other data
19 supplied in order that instructions can be issued to the CPU
20 1, in cooperation with the operating system and in order to
21 implement the present invention. These programs, code and
22 data are loaded into the main memory 4 for execution. The
23 computer program code can be compressed, or it can be
24 divided into a plurality of codes and recorded using a
25 plurality of media. The programs can also be stored on
26 another a storage medium, such as a disk, and the disk can
27 be driven by another computer.

1 The system 100 further includes user interface hardware.
2 User interface hardware components are, for example, a
3 pointing device (a mouse, a joy stick, etc.) 7 or a keyboard
4 6 for inputting data, and a display (CRT) 12. A printer,
5 via a parallel port 16, and a modem, via a serial port 15,
6 can be connected to the communication terminal 100, so that
7 it can communicate with another computer via the serial port
8 15 and the modem, or via a communication adaptor 18 (an
9 ethernet or a token ring card). A remote transceiver may be
10 connected to the serial port 15 or the parallel port 16 to
11 exchange data using ultraviolet rays or radio.

12 A loudspeaker 23 receives, through an amplifier 22, sounds
13 and tone signals that are obtained through D/A
14 (digital-analog) conversion performed by an audio controller
15 21, and releases them as sound or speech. The audio
16 controller 21 performs A/D (analog/digital) conversion for
17 sound information received via a microphone 24, and
18 transmits the external sound information to the system. The
19 sound may be input at the microphone 24, and the compressed
20 data produced by this invention may be generated based on
21 the sound that is input.

22 It would therefore be easily understood that the present
23 invention can be provided by employing an ordinary personal
24 computer (PC), a work station, a notebook PC, a palmtop PC,
25 a network computer, various types of electric home
26 appliances, such as a computer-incorporating television, a
27 game machine that includes a communication function, a

1 telephone, a facsimile machine, a portable telephone, a PHS,
2 a PDA, another communication terminal, or a combination of
3 these apparatuses. The above described components, however,
4 are merely examples, and not all of them are required for
5 the present invention.

6 Advantages of the Invention

7 According to the present invention, provided is a method and
8 a system for embedding, detecting or updating additional
9 information embedded in compressed audio data, without
10 having to decompress the audio data. Further, according to
11 the method of the invention, the additional information
12 embedded in the compressed audio data can be detected using
13 a conventional watermarking technique, even when the audio
14 data have been decompressed.

15 The present invention can be realized in hardware, software,
16 or a combination of hardware and software. The present
17 invention can be realized in a centralized fashion in one
18 computer system, or in a distributed fashion where different
19 elements are spread across several interconnected computer
20 systems. Any kind of computer system - or other apparatus
21 adapted for carrying out the methods described herein - is
22 suitable. A typical combination of hardware and software
23 could be a general purpose computer system with a computer
24 program that, when being loaded and executed, controls the
25 computer system such that it carries out the methods
26 described herein. The present invention can also be embedded

1 in a computer program product, which comprises all the
2 features enabling the implementation of the methods described
3 herein, and which - when loaded in a computer system - is
4 able to carry out these methods.

5 Computer program means or computer program in the present
6 context mean any expression, in any language, code or
7 notation, of a set of instructions intended to cause a system
8 having an information processing capability to perform a
9 particular function either directly or after conversion to
10 another language, code or notation and/or reproduction in a
11 different material form.

12 It is noted that the foregoing has outlined some of the more
13 pertinent objects and embodiments of the present invention.
14 This invention may be used for many applications. Thus,
15 although the description is made for particular arrangements
16 and methods, the intent and concept of the invention is
17 suitable and applicable to other arrangements and
18 applications. It will be clear to those skilled in the art
19 that other modifications to the disclosed embodiments can be
20 effected without departing from the spirit and scope of the
21 invention. The described embodiments ought to be construed
22 to be merely illustrative of some of the more prominent
23 features and applications of the invention. Other beneficial
24 results can be realized by applying the disclosed invention
25 in a different manner or modifying the invention in ways
26 known to those familiar with the art.

27

[Equation 1]

$$M_k = \sum_{n=0}^{N-1} X_n \cos \left\{ \frac{2\pi}{N} \left(n + \frac{N}{4} + \frac{1}{2} \right) \left(k + \frac{1}{2} \right) \right\}$$

[Equation 2]

$$R_k = \sum_0^{N-1} X_n \cos \left\{ \frac{2\pi}{N} kn \right\}$$

$$I_k = - \sum_0^{N-1} X_n \sin \left\{ \frac{2\pi}{N} kn \right\}$$

[Equation 3]

$$R = \sum_{b=1}^{n+1} T_{r,b}^T M_b$$

$$I = \sum_{b=1}^{n+1} T_{r,b}^T M_b$$

[Equation 4]

$$R = \sum_{b=1}^{n+1} T_{W,r,b}^T M_b$$

$$I = \sum_{b=1}^{n+1} T_{W,r,b}^T M_b$$

[Equation 5]

$$\begin{aligned}
 M_b &= T_{r,b} R + T_{i,b} I \\
 &= \sum_{k=1}^{N/2} (R_k V_{r,b,k} + I_k V_{i,b,k})
 \end{aligned}$$

[Equation 6]

$$\begin{aligned}
 R_k &= V_{r,b,k} \cdot M_b \\
 I_k &= V_{i,b,k} \cdot M_b
 \end{aligned}$$

[Equation 7]

$$\begin{aligned}
 [a] \quad u_{r,b+m,k} &= u_{r,b,k} \\
 [b] \quad u_{r,b+m,k} &= -u_{r,b,k} \\
 [c] \quad u_{r,b+m,k} &= -u_{i,b,k} \\
 [d] \quad u_{r,b+m,k} &= u_{i,b,k}
 \end{aligned}$$